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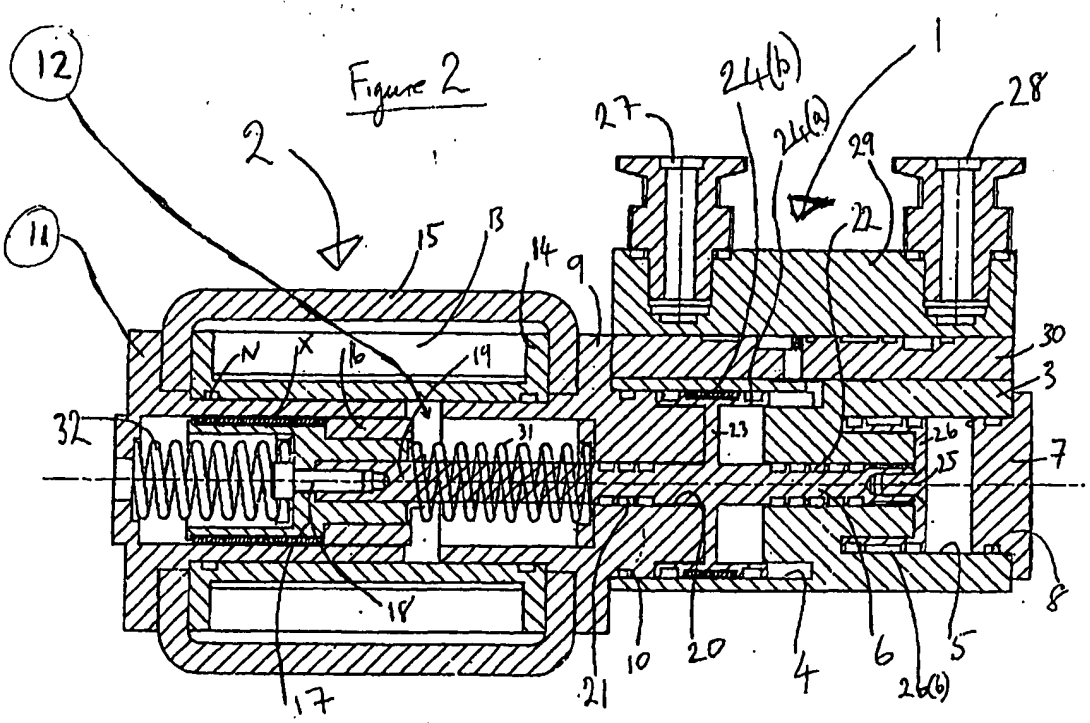
(54) Improvements in vacuum pumps

(57) A vacuum pump which comprises a multi-stage reciprocating piston mode of operation in which piston reciprocation is effected by electromagnetic drive means and a counter-acting spring means and in which the pump stages are connected in series between a pump inlet and a pump outlet such that, in use, gas being transferred through the pump passes through the stages in turn.

Figure 2



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Description

This invention relates to improvements in vacuum pumps and, more particularly, to such pumps incorporating a reciprocating piston.

There is a general need for small, dry (ie oil-free in operation) vacuum pumps for use in a variety of scientific and analytical purposes and for use in the backing of other vacuum pumps including turbo-molecular pumps in particular.

Current pumps include diaphragm pumps, but these have a limited diaphragm life expectancy (typically 6000 hours).

Vacuum pumps incorporating a reciprocating piston mode of operation are known which have an electromagnetic actuator comprising a wound coil and an iron core arrangement and a piston with a magnetic member at one end positioned within the electromagnet. Repeated magnetisation and de-magnetisation of the electromagnet by passing half wave rectified pulses of alternating current or pulsed direct current through the coil causes the magnetic member fixed to the piston arrangement to move within the cylindrical coil and causes fluid to be sucked in to a cylinder and then be exhausted therefrom at each piston cycle aided by the use of one-way valves in a manner known per se.

Such pumps have, however, not been generally applied to low pressure applications, for example below 100 mbar absolute, due to their general relative lack of overall vacuum performance.

The present invention is concerned with the provision of an electromagnetically actuated piston based vacuum pump which generally affords the possibility of such greater efficiencies and improved vacuum performance.

In accordance with the invention, there is provided a vacuum pump which comprises a multi-stage reciprocating piston mode of operation in which piston reciprocation is effected by electromagnetic drive means and a counter-acting spring means and in which the pump stages are connected in series between a pump inlet and a pump outlet such that, in use, gas being transferred through the pump passes through the stages in turn.

The term "multi-stage" used herein means a minimum of two stages. Preferably, however, pumps of the invention possess three or four or more stages in series.

Preferably also, the pump possesses one or more double acting piston heads with each such piston head defining two pump stages, ie one on either side of the piston head, within the cylinder with which it is associated. A pump with four stages comprising two double acting pistons is most preferred.

In preferred embodiments of the invention, the pump possesses one or two or more of such double acting piston heads contained within the same cylinder block. Advantageously, all such piston are present on the same piston shaft.

The preferred form of electromagnetic drive means is a solenoid actuator operating on half wave rectified AC current or pulsed direct current which during the magnetisation period with current flowing through the coils of the solenoid drives a magnetic plunger to which the piston is attached to bridge an air gap in an iron core surrounding the coils.

The general features of the invention are particularly suited to preferred embodiments in which all the pump stages are present on one side of the pump drive means.

In such preferred embodiments and generally, it is advantageous for one or both of:

the pump piston heads all to be present on the same piston shaft and for the piston shaft to be positioned for reciprocation along the main axis of the pump, and

the pump piston shaft to pass centrally through the electromagnetic drive means.

The above advantageous features allow for the possibility of a bearing to be mounted on the plunger arrangement utilising the internal surfaces of the iron core pole pieces of the solenoid as bearing surfaces during reciprocation of the plunger and an attached piston shaft, thereby ensuring concentricity between the plunger and the iron core pole pieces. Such advantageous features also afford the possibility of cooling the solenoid from the outside, ie from outside the vacuum envelope of the pump, leading to a potential longer life for the solenoid and the pump as a whole.

Each stage of the pumps of the invention require in general one way valves to allow, at relevant positions of the piston head within its cylinder, gas to enter the stage from the pump inlet or previous stage and also to allow gas to be exhausted from that stage and to pass in to the subsequent stage or the pump outlet.

In preferred embodiments in which all the pump stages are situated on one side of the pump drive means, it has been found to be advantageous for all such valves to be present in a single valve plate attached to an external surface of the cylinder block and which can be removed for easy maintenance.

Preferably such a single valve plate is positioned intermediate the cylinder block and a manifold in which are defined a pump inlet, outlet, and the various passageways and parts required to link each pump stage in series via the valves of the valve plate.

An important feature of the invention is the spring means used in the pump to counter-act the drive means in those parts of the electromagnetic cycle when the coils are not magnetised. The use of such a spring means is essential for obvious reasons.

However, in addition to such a counter-acting spring means, it has also been found to be advantageous to employ a further spring means acting in the same direction as the electromagnetic drive means to counteract

the forces generated by the pressure differentials across the piston faces at lower inlet pressures, thereby balancing the piston arrangement in a relatively central stroke position.

In the case of a solenoid actuator of the type described above in particular, it has been found that the use of such counter-acting spring means can act, in conjunction with the solenoid drive means, to effect a resonant system. In such a system, it is clear that the force exerted by the two spring means on the plunger/piston must be carefully chosen but this is readily achievable by those skilled in the art.

Good inter-stage vacuum seals within the pump and, in particular, on the piston shaft are essential to good performance of the pump. A plurality of seals of known design can usefully be employed along the length of the shaft/head, for example contained in grooves around the peripheries of the shaft/head component(s).

For a better understanding of the invention, reference will now be made, by way of exemplification only, to the accompanying drawings in which:

Figure 1 is a schematic perspective view of a pump of the invention, partly exploded to show a valve plate and a manifold thereof more clearly, and

Figure 2 is a schematic sectional view through the pump of Figure 1 along the line II-II of Figure 1 but with the valve plate and the manifold in position.

With reference to the drawings there is shown a piston pump 1 of the invention having as an integral part thereof a solenoid drive means 2.

A substantially square cross-section body member 3 has defined therein two circular diameter bores 4,5 linked by a further circular bore 6. The bore 5 of the body member 3 is sealed by the circular end plate 7 by means in particular of circumferential seal 8.

The other end of the body member 3 is sealed to a first iron core pole piece 9 of the solenoid drive means 2 by means of a further circumferential seal 10.

A further iron core pole piece 11 of the same generally circular cross sectional size as the piece 9 is present which define an air gap 12 therebetween.

A wound coil 13, supported and electrically insulated by a plastic bobbin 14, is enveloped by the iron core, comprising the aforementioned iron core pole pieces 9,11 and laminated iron cage 15, thereby completing, with a plunger described below, the solenoid drive means 2.

The pump being sealed from atmosphere at the solenoid end by means of circumferential sealing 'N' between the plastic bobbin 14 and core pole pieces 9,11, providing an overall hermetically sealed unit from inlet to exhaust, suitable for handling toxic process gases.

The solenoid plunger 16 is of hollow cylindrical shape and is sized externally to fit closely the internal cylindrical surface of the core pole pieces 9,11 and therefore is adapted to reciprocate axially therein. A solenoid bearing 'X' mounted on the same means as the plunger 16 provides concentricity between the plunger and pole pieces 9,11. To maintain the running surface quality for the bearing X, and to avoid corrosion of the iron components, the surfaces of the core pole pieces 9,11 and plunger 16 are advantageously coated with a suitable coating, for example Hard Chrome.

The plunger 16 is attached to a plunger carrier 17 which is itself securely fitted by means of a bolt 18 to a piston shaft 19.

The piston shaft 19 extends through a circular bore 20 in the pole piece 9 and is sealingly adapted for axial reciprocation therein by means of a series of shaft seals 21 contained in a plurality of circumferential grooves in the external surface of the shaft 19.

The piston shaft 19 further extends through the circular bore 6 in the body member 3 and is again sealingly adapted for axial reciprocation therein by means of a further series of shaft seals 22 contained in a plurality of circumferential grooves in the external surface of the shaft 19.

The piston shaft 19 has integrally formed therewith a double acting piston head 23 having a cylindrical outer portion which is sealingly adapted for reciprocation within the bore 4 of the body member 3. A central bearing 24(b) and an outer seal arrangement 24(a) is contained in a plurality of circumferential grooves in the external surface of this cylindrical outer portion of the piston head 23.

The piston shaft also has attached thereto by means of a bolt 25 a further piston head 26 which also has a cylindrical outer portion which is sealingly adapted for reciprocation within the bore 5 of the body member 3. A series of seals 26(b) are contained in three circumferential grooves in the external surface of this cylindrical outer portion of the piston head 26.

The piston head 23 therefore defines the first two stages of the pump, one being to the left (as shown) of the piston head 23 and the second being to the right (as shown) of the piston head 23.

The piston head 26 defines the third and fourth stages of the pump, the third being to the left (as shown) of the piston head 26 and the fourth being to the right (as shown) of the piston head 26.

In Figure 1, the piston arrangement is shown in a position to the left, so that the volumes associated with the second and fourth stages being "open" and the volumes associated with the first and third stages being "closed".

The body member 3 can therefore be regarded as a single cylinder block of the pump sealed at one end by the end plate 7 and at the outer end by the pole piece 9.

The pump has an inlet 27 and an outlet 28 between which are provided passageways for gas drawn in to the inlet 27 to pass through the four stages in series and

sequentially before being exhausted through the outlet 28.

In accordance with preferred embodiments of the invention, the inlet 27 and outlet 28 are formed in to a manifold 29 which also provides the necessary passageways for transmission of the gas through the four stages of the pump in conjunction with a single valve plate 30 sandwiched between the body portion 3 and the manifold 29 in which one way valves are present to allow entry in to and exhaust from each chamber is allowed at relevant times during the piston cycle. The use of such a manifold and valve plate allows for a more simple construction of the pump and more ready maintenance thereafter.

Associated with the plunger carrier 17 are two coil springs 31 and 32. The spring 31 is required to exert a force on the plunger carrier 17, and hence on the piston arrangement 19 as a whole, to urge it back to the position shown in Figure 1 where no current is passing through the coil 13, ie when the electromagnetic actuator is inactive. At lower pressures, this force is complemented by pressure differential forces acting on the piston-faces in the same direction. In that part of the cycle when the actuator is active, the movement of the plunger to bridge the gap 12 in the pole pieces 9,11 exerts a compressive force on the spring 31.

The spring 32 acts in a direction to complement the electromagnetic force of the solenoid drive 2. Optimisation of the balancing of the dynamic forces exerted by this spring on the plunger carrier 17, coupled with the magnetic force acting on the plunger 16, relative to that exerted in the opposite direction by the spring 31 and pressure differential forces results in the provision of a drive mechanism system which is resonant and provides preferably stroke characteristics. Such a resonant system is aided by use of the features, particularly the preferred embodiments, of the invention.

In use of the pumps of the invention, the application to the electromagnetic drive means, preferably the solenoid actuator, of a half wave rectified AC pulsed current during a half cycle of the piston and aided in particular by the force exerted by the spring 32 and utilising the force exerted by the spring 31 in the opposite direction during the other half cycle of the piston affords the opportunity of the setting up of a resonant action for the piston and for the pump as a whole which leads to enhanced pump efficiency.

Spring adjustment means for either or both of the springs 31, 32 although not shown in the drawings may be incorporated to enable the force(s) extended by the springs to be adjusted in situ.

Claims

1. A vacuum pump which comprises a multi-stage reciprocating piston mode of operation in which piston reciprocation is effected by electromagnetic drive means and a counter-acting spring means and in which the pump stages are connected in series between a pump inlet and a pump outlet such that, in use, gas being transferred through the pump passes through the stages in turn.

2. A pump according to Claim 1 having at least three stages in series.

3. A pump according to Claim 1 or Claim 2 which possesses one or more double acting piston heads with each such piston head defining two pump stages within the cylinder with which it is associated.

4. A pump according to any preceding claim in which all the pump stages are present on one side of the pump drive means.

5. A pump according to any preceding claim in which the pump piston heads are all present on the same piston shaft and the piston shaft is positioned for reciprocation along the main axis of the pump.

6. A pump according to any preceding claim in which the pump piston shaft passes centrally through the electromagnetic drive means.

7. A pump according to any preceding claim having a single valve plate in which one way valves are present to allow entry in to and exhaust from each stage at relevant times of the piston cycle.

8. A pump according to any preceding claim in which a first spring means complements the electromagnetic force of the drive means and a second spring means acts in the opposite direction on the drive means to provide a resonant system.

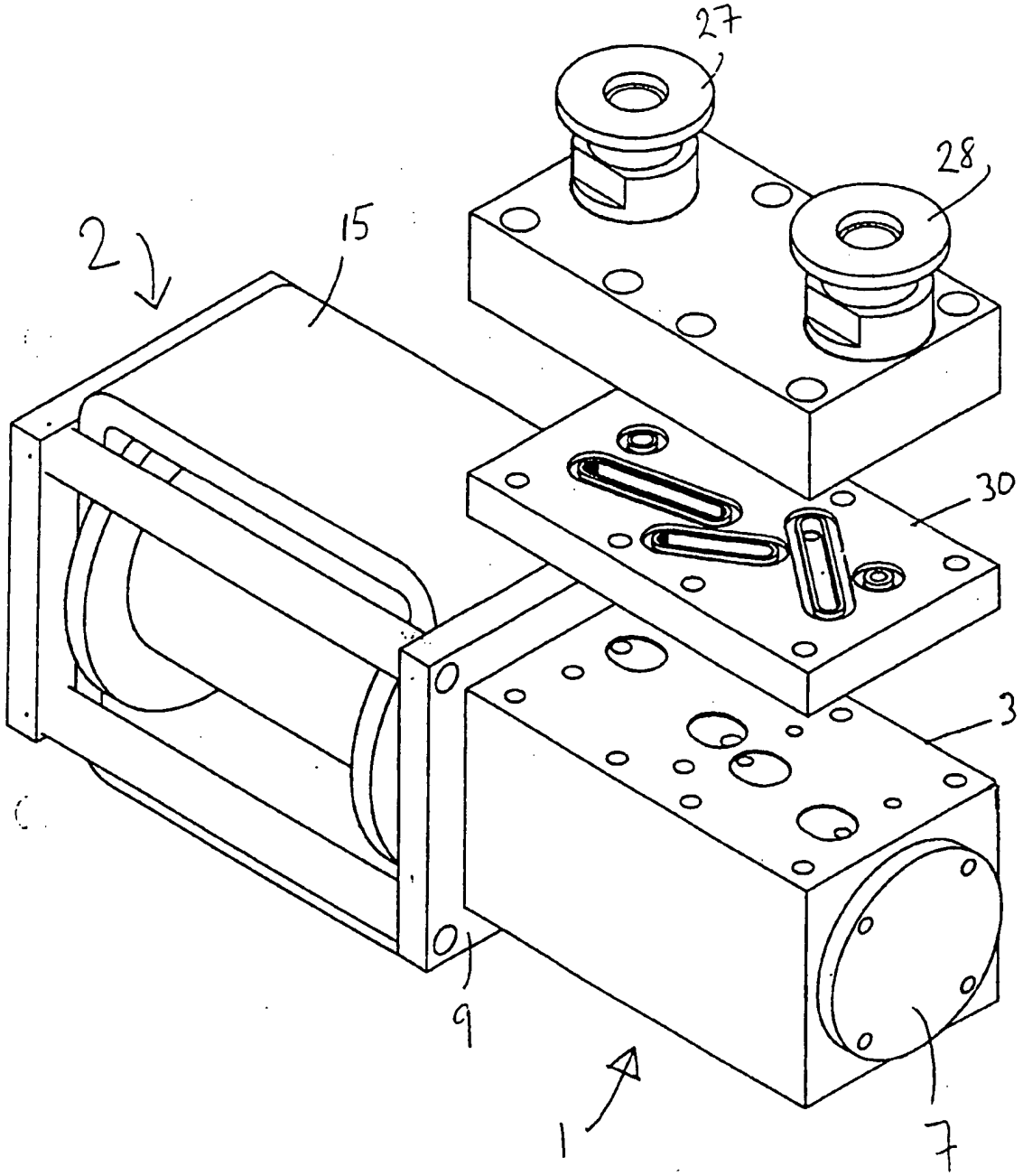

FIGURE 1

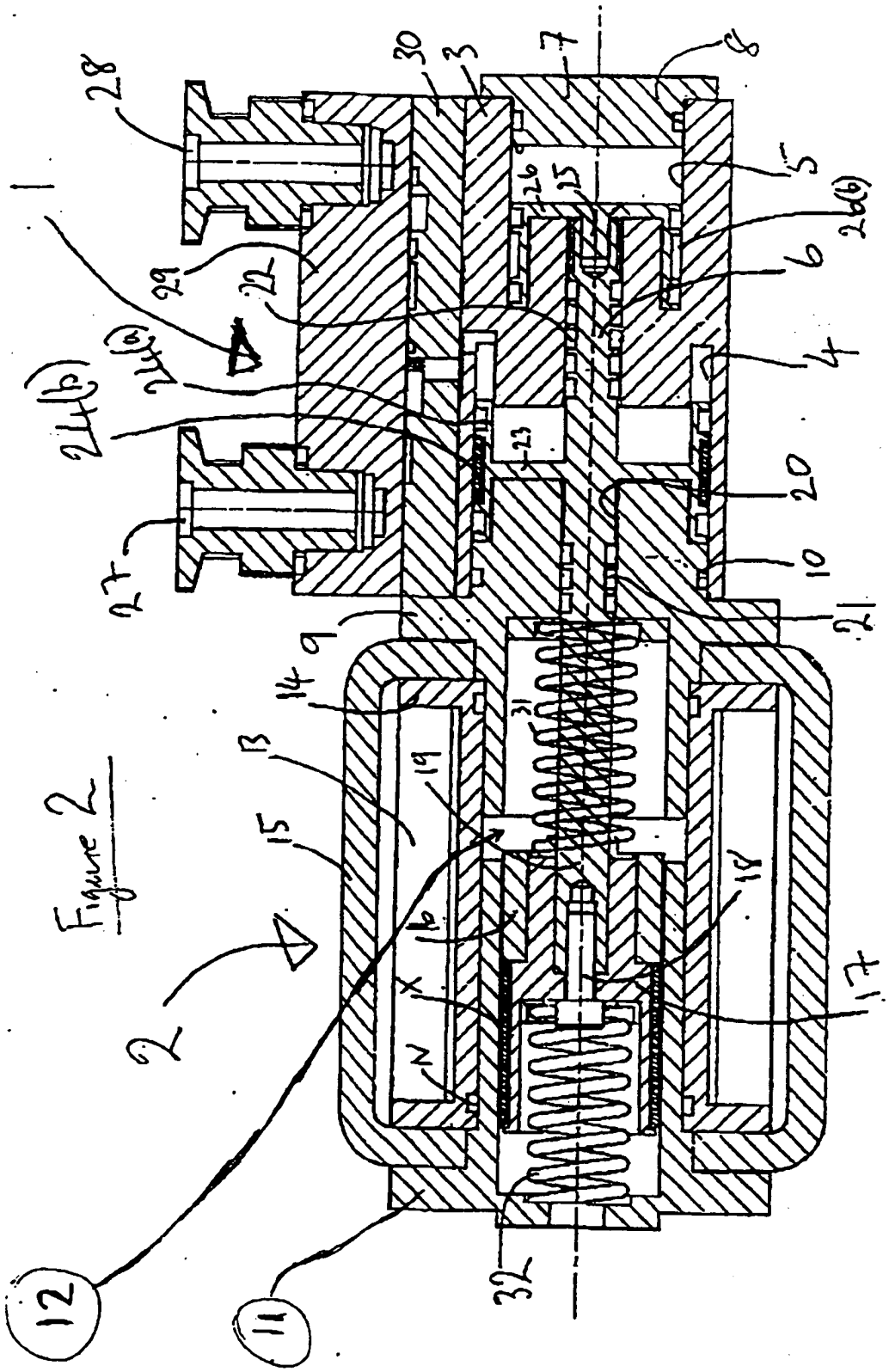
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Figure 2

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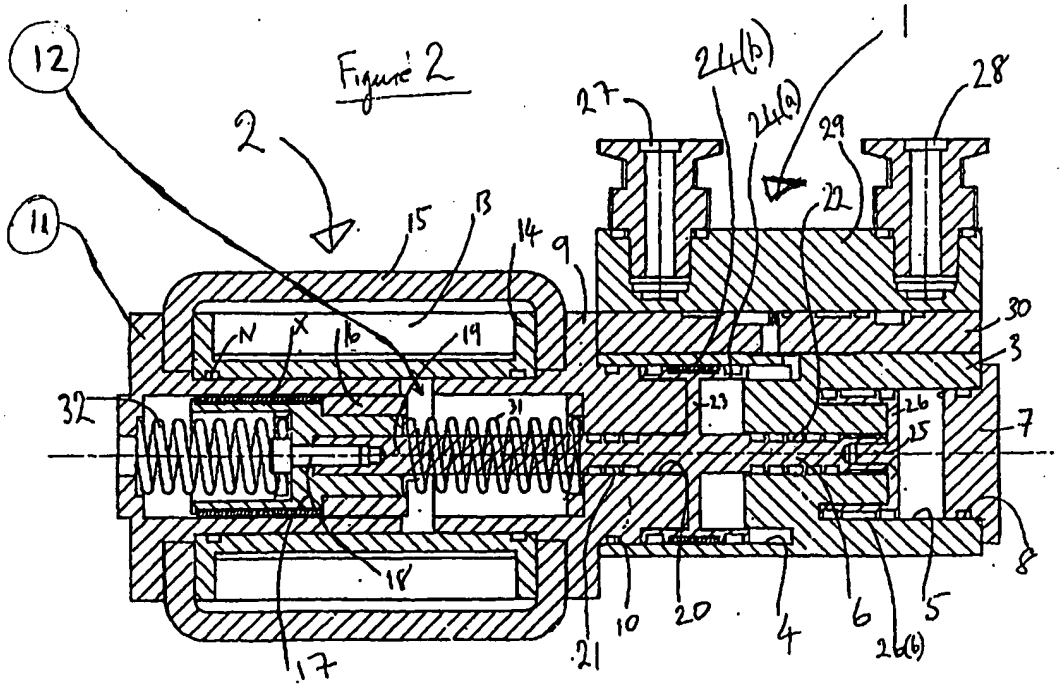

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EUROPEAN SEARCH REPORT

Application Number
EP 97 30 1303

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Place of search	Date of completion of the search	Examiner
THE HAGUE	8 April 1999	Ingelbrecht, P

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